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STUDY OF THE CUMULATIVE EFFECT OF IMPACT ACCELERATIONS

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ABSTRACT. Experiments on rats were performed to study the cumulative effect of impact accelerations of 600 g revealed at postmortem examinations. The accelerations were applied at different intervals and subcritical landing velocities. The cumulative lesions resulting from repeated exposures with an hour interval were detected as the primary lesion of the lungs similarly to the effect of a single exposure at supercritical velocities. Lesions developed after a comparatively small number of repeated exposures (3 to 5) for a wide range of subcritical velocities (7 to 4 - 5 m/sec). The aftereffect period covers over 24 hours and is related to reactive changes in individual organs.

Only a few studies of the effect of accelerations on the organism have been made, although the determination of resistance to accelerations of various kinds may lead to incorrect practical recommendations unless their cumulative effect is taken into account.

D.I.Ivanov described the unfavorable action of cumulation on pilots subjected to repeated accelerations in flight. Asthenization of the body intensified the cumulative effect. In this connection, it was not by chance that attention has been directed primarily to the cumulative manifestations of pelvis-head accelerations where the resistance of the body is lowest (S.A.Gozulov, 1956). Many authors have mentioned various aspects of the cumulative effect in centrifugal accelerations (Duane et al.; Beckman et al.; P.F.Vokhmyanin; B.M. Savin; I.M.Khazen et al.; and others), noting increased functional and microstructural disturbances and changes in adaptive and protective reactions with decreasing interval between the repeated actions, with increasing acceleration, and, particularly, with its increased duration.

The literature contains few data on the cumulative effect of impact accelerations. Authors who actually observed such effects correlated them primarily with the number of repeated actions and with their interval (M.I.Kas'yanov and G.P.Mirolyubov). After repeated action (up to 27 times) of impact accelerations (from 35 to 300 g) on rats and dogs, destructive and dystrophic changes were noted in various organs and tissues. After shock accelerations of 200 - 300 g, repeated up to 3 - 5 times, atrioventricular block occurred and, in some cases, ventricular fibrillation. Pathological findings showed severe lesions of lung, liver, intestines, and other organs. When the interval between the actions was lengthened from 10 - 15 min to 2 - 5 days and the accelerations were somewhat decreased (to 100 - 200 g), so pronounced an effect was no longer

* Numbers in the margin indicate pagination in the foreign text.

induced (S.A.Gozulov et al., 1964).

Earlier studies thus not only established the fact of cumulation of the harmful effect, but also determined the correlation between effect and interval.

For practical purposes, it was necessary to make a more detailed study of this relationship and to estimate the allowable number of repeated impact accelerations when their value, for instance on landing, is close to the limit. /23

This study was performed on a stand where accelerations of the order of 600 g, 1.2 - 0.8 m/sec in duration, were applied. The rate of increase of the accelerations exceeded 500,000 g/sec. In all, 48 experiments were performed on 97 white rats. The animals were attached to a platform permitted to fall on a lead crusher in such a way that the acceleration had the direction spine-thorax. The assigned height determined the speed at the instant of impact while the deformation of the crusher determined the deceleration path, from which the mean value and time of action of the acceleration was calculated. The acceleration was held as constant as possible in all experiments. The results of the acceleration were estimated from the pathomorphological changes noted in the animals, which were sacrificed by giving ether immediately after the experiment.

In a preliminary series of studies (10 rats), we determined the speed causing minimum lesions under these conditions after a single landing (critical speed). This was found to be 8 - 9 m/sec, and the acceleration produced at this velocity was 550 - 650 g. As a control, the effect of a single acceleration was determined on several rats before each series of experiments, as was also the effect of different experimental conditions (attachment, method of sacrifice, etc.) without the action of acceleration. Isolated or multiple petechial hemorrhages were found in the lungs of many of these controls. Therefore, in determining the results of the accelerations, only the more severe pulmonary changes as well as the gross lesions in the other organs were taken into account.

In three successive series of experiments we studied the effect of repeated accelerations at intervals of 2 - 3 min, 60 min, and 1 day.

For series I (Table 1) the landing speed was decreased uniformly from near the critical level (7 m/sec) to a relatively low value (4 m/sec).

Table 1 indicates that, after repeated accelerations with a short interval and a landing speed of 7 m/sec, considerable pulmonary lesions are already prevalent after 3 - 4 repetitions, and changes in the liver also appear. These changes increase with the number of accelerations.

In the following experiments, in spite of the reduction of speed to 6 m/sec, pronounced lesions of the lungs appeared after the same number of repetitions, whereas at 5 m/sec they were noted only after one or two more accelerations. At the same time, liver damage appeared after a somewhat greater number of accelerations (5 - 6 for a speed of 6 m/sec); at 5 m/sec they were not noted even after 7 accelerations.

At 4 m/sec there was a sharp change in the relation observed in the earlier experiments: lung damage now appeared only after 14 accelerations. No liver damage at all resulted.

TABLE 1

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REPEATED ACTION OF IMPACT ACCELERATION (450 - 600 g)
AT 2 - 3 MIN INTERVAL

Landing Speed, m/sec	Number of Accelera-tions	Number of Animals	Character of Lesions
7	2	3	Lungs: single and coalescent petechial and single superficial focal hemorrhages.
7	3 - 4	7	Lungs: multiple petechial and deep focal hemorrhages; in 2 cases only petechial hemorrhages. Liver: no lesions in 4 cases; subcapsular lacerations observed in 1 case.
7	5 - 6	4	Lungs: multiple deep hemorrhages, focal or covering entire lobes in all cases. Liver: multiple lacerations along the edges and at the radix; no lesions in 1 case.
7	7 - 8	3	Lungs: multiple deep focal hemorrhages. Liver: multiple lacerations.
6	2	2	Lungs: in one case coalescent petechiae and a small focal hemorrhage.
6	3 - 4	4	Lungs: massive hemorrhages in all cases.
6	5 - 6	6	Lungs: multiple deep focal and massive hemorrhages; in one case petechial and focal superficial hemorrhages. Liver: no lesions in 3 cases; single and multiple lacerations observed in 3 cases.
5	3 - 4	4	Lungs: in 2 cases, single small hemorrhagic foci.
5	5	3	Lungs: pronounced superficial and deep focal hemorrhages in 2 cases, and no lesions in 1 case.
5	7	2	Lungs: deep focal hemorrhages in one case and small focal hemorrhages in the other.
4	4 - 6	4	Lungs: in all cases, small single hemorrhagic foci.
4	8 and 10	4	Lungs: in all cases, insignificant single hemorrhages.
4	14	4	Lungs: deep focal hemorrhages in 3 cases. Small single superficial hemorrhagic foci in 1 case.

Thus, in these experiments a zone of cumulation of the harmful effect can be distinguished, bounded on the one hand by a relatively small number of accelerations (3 - 5) and on the other by a considerable range of speeds (from 7 to 4 - 5 m/sec). These speeds may be conveniently termed subcritical.

Certain differences in the severity of the damage might have been due to fluctuations in the accelerations, which amounted to 100 - 150 g. Although this was significant for individual results, it still could not change the general tendency. Moreover, a comparison of the individual cases showed that, in spite of the fluctuations of acceleration from 450 to 600 g, the very same picture of damage was often observed, and the more severe cases frequently followed an even lower acceleration. It is possible that additional factors affecting the re- /24
sistance of the animals (details of attachment, motion of the animals before impact, etc.) determined the character of the various results.

In the next two series of experiments we investigated the effect of impact accelerations of the same values at a speed of 6 m/sec, repeated at intervals of 1 and 24 hrs (Table 2).

Table 2 shows that, on increasing the interval between the accelerations to 1 hr, it took only one or two more applications (7 - 8 in all) to induce pronounced changes in the liver. Pulmonary lesions appeared after the same number of applications as in the series with a 2 - 3 min interval.

At a still longer interval (1 day), the character of the lesions changed: the accelerations, in spite of their great number (as many as 10), induced no significant changes in the lungs. Liver lesions appeared most frequently after the 9 - 10^{th} application, i.e., 1 to 2 impacts earlier than in the preceding series.

Thus, it can be stated that the lung is the organ most vulnerable both to a single acceleration at critical speeds and to repeated action at subcritical landing speeds. Shock acceleration also has a shorter period of aftereffect /25
for the lungs than for the liver.

The existence of cumulation when the intervals between accelerations are long indicates the considerable duration of the period of aftereffects, which is determined either by the depth of the lesions caused by the direct effect of acceleration, or by the resultant reactive state. It seems more probable that the determining factor is the summation of microtraumata, which, in turn, diminishes the resistance of the tissues to the repeated mechanical action and modifies the functional state of the organism and its resistance as a whole. Shock accelerations of the characteristics investigated have a pronounced cumulative harmful effect, which depends to a greater degree on the total number of repeated actions than on their interval. The length of the interval (its fluctuations) has no substantial effect on the cumulative effect within the limits of the aftereffect period.

The ratio of landing speed to its critical value is important for the manifestation of the cumulation of shock accelerations. In the zone of speeds close to critical, the cumulative effect increases rapidly.

TABLE 2

REPEATED ACTION OF SHOCK ACCELERATION (500 - 600 g) WITH INTERVAL OF 1 HR AND 24 HRS

Landing Speed, m/sec	Number of Accelera-tions	Interval (hrs)	Number of Animals	Character of Lesions
6	3 - 4	1	4	Lungs: multiple petechial and single superficial focal hemorrhages.
6	5	1	2	Lungs: multiple deep focal hemor-rhages.
6	7 - 8	1	4	Lungs: massive hemorrhages, entopic in the entire lobes in 3 cases; multiple focal hemorrhages in 1 case. Liver: small single hemorrhagic foci in 3 cases; no lesions in 1 case.
6	5	24	2	Lungs: single petechial hemorrhage.
6	7 - 8	24	4	Lungs: single or multiple petechial hemorrhages; in 1 case, single focal hemorrhage. Liver: no lesions in 3 cases; deep necrosis, hematoma, and adhesions along edge in 1 case.
6	9 - 10	24	6	Lungs: single petechial hemorrhage; in 1 case, single deep hemorrhage. Liver: deep necrosis, lacerations, adhesions, and hematoma; in 1 case, single laceration.

For a more detailed elucidation of the laws of appearance, and the mechanisms of development, of the cumulative effect in shock actions on the animal or human body, further research is required. In particular, it is of practical importance to determine the allowable intervals between the action of shock accelerations, for various parameters of such accelerations.

REFERENCES

1. Vokhmyanin, P.F.: In: Aviation and Space Medicine (V kn.: Aviatsionnaya i kosmicheskaya meditsina). p.115, Moscow, 1963.
2. Gozulov, S.A.: Voyenno-Med. Zh., No.10, p.55, 1956.
3. Gozulov, S.A., Mirolyubov, G.P., Popov, N.I., et al.: Kosmich. Issled., Vol.2, No.5, p.805, 1964.
4. Kas'yanov, M.I. and Mirolyubov, G.P.: In: Aviation and Space Medicine (V kn.: Aviatsionnaya i kosmicheskaya meditsina). p.236, Moscow, 1963.

5. Savin, B.M.: In: Aviation and Space Medicine (V kn.: Aviatsionnaya i kosmicheskaya meditsina). p.426, Moscow, 1963.
6. Khazen, I.M., Kogan, E.M., and Barer, A.S.: In: Aviation and Space Medicine (V kn.: Aviatsionnaya i kosmicheskaya meditsina). p.469, Moscow, 1963. /26
7. Beckman, E.L., Ziegler, J.E., Duane, T.D., et al.: In: Questions of Space Medicine. p.74, Moscow, 1954.
8. Duane, T.D., Wechsler, R.L., Ziegler, J.E., et al.: In: Questions of Space Medicine. p.91, Moscow, 1954.

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